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DEADLINE COST MODEL STUDY

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This study develops a generalized model used to quantify the cost incurred by the Army when an equipment unit is deadlined. The force-level model developed used float factor, acquisition cost, service life, repair and maintenance cost, crew cost and an impact cost as inputs to develop sample deadline costs for the M551, M163, M167, and M109. A sensitivity analysis on these sample items indicated that the model has considerable stability and is not greatly sensitive to input estimation errors.

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I. INTRODUCTION

A memo from the Commanding General (CG), ARMCOM, 3 December 1973, to Systems Analysis Directorate established the need to develop a generalized model which would quantify the costs, direct and indirect, which are incurred by the Army when an item of equipment is deadlined. "Deadline" used in the context of this study is taken to mean, "the removal of an item of equipment and its crew from operation or immediate operational readiness because of actual or potential mechanical, electrical, and safety device failure[1]. In his memo, the CG made reference to a practice used by the construction industry which equates the cost of a deadline to the cost of having to rent a similar piece of equipment. While this approach apparently works well in the construction industry where project completion schedules and/or penalty clauses are of sufficient impact to force the contractor to rent equipment, is it applicable to the military situation? A shortcoming of the construction industry approach is that it does not include such costs as operator/crew downtime or the cost of the repair and maintenance actions necessary to keep the equipment in service.

The results of this study should be considered for incorporation into the present logistics models which currently consider only the direct inventory costs identified to the PEMA and/or O&MA appropriations.

II. SCOPE OF THE STUDY

The initial phase of the study consisted of a literature search. Upon finding the available literature void of similar or related studies, four initial approaches to the model were developed and presented to the CG, ARMCOM for his consideration. The CG responded by indicating that, of the four alternatives presented, the generalized deadline model which addresses those costs specifically associated with the deadline/failure event should be pursued. The reader is cautioned that this aprroach is not all inclusive because indirect costs such as mission abort are not included. Initial testing of the model was conducted on the Howitzer, M109A1; Vulcan Air Defense System, M163 and M167; and the ARAAV, M551.

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[1] AR 310-25 defines deadlined equipment as follows: "Any major end item of authorized equipment charged to a using unit or agency which has been removed from operation or immediate operational readiness because of actual or potential mechanical, electrical, or safety device failure. It does not include equipment scheduled for routine preventive maintenance or inspection."

In response to the direction of the CG, the following unit-level deadline cost model was developed:

$$C_{D1} = F_1\left[C_{R1} + (C_C)(D_{T1})\right] + F_2\left[C_{R2} + C_C\,(D_{T2})\right] + F_3\left[\left(\frac{(A_C)}{S}\right)(D_{T3}) + T_C + C_{R3} + C_C(T_T)\right]$$

where

C_{DL} = Average cost of a deadline

A_C = Acquisition cost/standard price

C_C = Average crew cost

F_1 = Portion of the repairs completed at the mission site $0 \leq F_1 \leq 1$ (Basic assumption is that mission site repairs do not require issuance of a float.)

F_2 = Portion of the repairs completed at the support level not requiring the issuance of a float, $0 \leq F_2 \leq 1$

F_3 = Portion of the repairs completed at the support level requiring the issuance of a float, $0 \leq F_3 \leq 1$

$F_1 + F_2 + F_3 = 1$

C_{R1} = Average repair cost for mission site repair

C_{R2} = Average repair cost for support level repairs not requiring a float

C_{R3} = Average repair cost for support level repairs requiring a float

D_{T1} = Average deadline time for the mission site repairs

D_{T2} = Average deadline time for support level repairs not requiring a float (includes transportation time to and from support organization)

D_{T3} = Average deadline time for support level repairs which require the issuance of a float

T_C = Transportation cost to bring a float to the mission site

T_T = Transportation time required to bring a float to the mission site

S = Unit service life

Data Impact on the Unit-Level Model Development was as follows:

The maintenance data collection system utilized by the Army prevented deriving or estimating values for some of the parameters (F_1, F_2, F_3, D_{T1}, D_{T2}, and D_{T3}) required in the above model. In addition, a recent publication[2] cited serious gaps existing in these maintenance records.

III. DEVELOPMENT OF A GENERALIZED FORCE-LEVEL DEADLINE COST MODEL

Upon reviewing existing data, it was discerned that force-level life cycle data are readily available or readily estimated.

In quantifying the cost of deadline, it is necessary to make a basic assumption that in the allocation of the defense budget to provide a given level of combat capability, the benefit lost from not having an item of equipment and its crew operationally available is at least equal to the cost of acquiring, operating, and maintaining that unit in the force structure. If this transformation of dollar resources into troop and hardware inventories has been properly effected, the marginal benefit derived from a given military operating unit should be at least equal to the marginal cost of that unit[3]. In this context the term "unit" denotes an item of equipment and its crew. The nonavailability of a deadlined item, therefore, reduces the overall value of our combat capability by an amount at least equal to the dollar resources consumed by that unit, prorated over the length of the downtime.

It is reasoned that the fiscal resources consumed in the acquisition of the item amortized over its life, plus repair, maintenance, and crew costs, make available a certain number of productive service days per period for a given unit. It is recognized that this is not the exact value lost when a specific unit is unavailable for service; but, rather,

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[2]Raymond Bell, et al., Technical Memorandum No. 164, Vehicle Average Useful Life Study for Truck Cargo; 2-1/2 ton, 6 X 6, M35A2, - US Army Materiel Systems Analysis Agency, Aberdeen Proving Ground, Maryland, October 1973.

[3]Richard H. Leftwich, The Price System and Resource Allocation, revised ed. Holt, Rinehart and Winston, New York, NY, 1963, p 318-319.

it is approximately the deadline cost incurred for the aggregate of end items of a given class utilized by the Army.

It is proposed in this study that the total unit cost per service day (i.e., the average cost of a given unit per day) incurred by the Army be a proxy for the deadline cost.

Therefore,

$$C = \frac{(1 + FF)(AC/SL + RMC) + CC}{365} + IC$$

C = Deadline cost per service day

FF = Float Factor

AC = Acquisition Cost/standard price

SL = Service Life in years

RMC = Annual Repair and Maintenance Cost

CC = Annual Crew Cost

IC = Impact Cost - i.e., the cost of other personnel and equipment dependent upon the deadlined unit for continued operation

IV. TRIAL RUN AND SENSITIVITY ANALYSIS

To test the model, data (Appendix A) was collected for the ARAAV, M551; VADS, M163 and M167; and Howitzer, M109A1; and entered into the model, Table 1.

TABLE 1 - FORCE MODEL INPUTS

	M551	M163	M167	M109A1
Float Factor	0.033	0.09	0.09	0.027
Acquisition Cost	$259,930	$276,377	$220,416	$145,812
Service Life	20 Yr	20 Yr	20 Yr	20 Yr
Crew Cost	$48,200/Yr	$47,580/Yr	$47,580/Yr	$96,675/Yr
Maintenance Cost	$30,736/Yr	$47,859/Yr	$36,443/Yr	$29,697/Yr

The results obtained from the force level model are shown in Table 2.

TABLE 2 - FORCE MODEL RESULTS

	M551	M163	M167	M109A1
Deadline Cost per Service Day	$256	$315	$272	$369
Percentage of Acquisition Cost	.098%	.11%	.12%	.25%

It is of interest to note the impact of the higher crew cost for the M109A1 upon the Deadline Cost per Service Day. Also, the difference in the Percentage of Acquisition Cost for the M551 and M109A1 would clearly indicate that these factors are item peculiar and not common to a commodity class of items.

Sensitivity analyses were conducted to determine model responsiveness to changes in data input and to identify those data elements which have the most significant effect on the independent variable deadline cost per service day. First, an analysis of the major independent variables was performed in which each of these variables was increased by one percent while holding all the other independent variables constant and observing the percentage change in the dependent variable, Table 3.

TABLE 3 - SENSITIVITY ANALYSIS

(MAJOR INDEPENDENT VARIABLES)

Independent Variable (1% Change)	M551	M163	M167	M109A1
	% CHANGE IN DEADLINE COST PER SERVICE DAY			
Float Factor	.016	.048	.043	.007
Acquisition Cost	.148	.131	.121	.056
Crew Cost	.340	.454	.400	.718
Maintenance Cost	.516	.414	.479	.227

As can be seen, crew cost and maintenance cost have the most significant effect on the deadline cost per service day. Adding the independent effects of the two variables yields a value in excess of 86 percent for the items of equipment subjected to this analysis.

To examine the sensitivity of the model at the account level, a similar analysis was conducted on each of the cost accounts which make up the annual crew and maintenance cost variables. For a one percent increase in each of the account variables, the percentage change in deadline cost per service day shown in Table 4, were observed.

TABLE 4 - SENSITIVITY ANALYSIS OF ACCOUNTS

ACCOUNT VARIABLE (1% Change)	M551	M163	M167	M109A1
	% CHANGE IN DEADLINE COST PER SERVICE DAY			
Crew Cost				
Crew, Pay and Allowance - MPA	0.356	0.271	0.320	0.477
Crew, Replacement Training	0.035	0.037	0.042	0.046
Crew, Overhead	0.124	0.101	0.117	0.194
Maintenance Cost				
Maintenance, Pay and Allowance - MPA	0.051	0.109	0.101	0.049
Maintenance, Replacement Trng	0.01	0.025	0.024	0.012
Maintenance, Crew Overhead	0.022	0.046	0.043	0.021
Consumption, Parts	0.166	0.202	0.182	0.115
Consumption, Pet Oils and Lub - OMA	INSIGN	INSIGN	INSIGN	INSIGN
Transportation - OMA	0.005	0.006	0.004	0.003
Depot Maintenance	0.077	0.065	0.047	0.027

It can be seen from this analysis that crew pay and allowance is the dominant factor, contributing nearly three times more to the deadline cost per service day than any other account. This variable, however, is easily computed based upon crew composite and pay grades and should have a very low estimating error. It should also be noted that for three of the four items studied, repair parts are the next most significant variable. Cost estimates prepared by the ARMCOM Cost Analysis Division, based upon repair parts demand history, provide reasonable estimates for this data element.

Since the independent variable service life has a non-linear relationship with the dependent variable deadline cost per service day, sensitivity calculation were made to observe the relationship between these two variables (Figures 1 through 4). As can be seen, service life does not effect the deadline cost per service day more than 10 percent providing the service life of the item does not fall below 12 years, using a base case life of 20 years. The percentage increases a little more than double when moving from a service life of 12 to 8 years. However, as service life is reduced to less than 8 years, the deadline cost per service day increases rapidly.

For the items studied, the variable impact cost (IC) was not included because the effected organizations could not be identified. It was, however, of interest to get some idea of the relative magnitude of the cost of deadline when impact costs are included. A test case was developed to determine the impact cost resulting from the deadline of a 225 ton/hour rockcrusher and the four Horizontal Construction Platoons of an engineer battalion, which depend upon it for material. It was found that when the rockcrusher was deadlined, 18 on-equipment crew personnel were idled, as compared to 85 personnel and their equipment (i.e., trucks, scrapers, etc.), who depend upon the output of the rock-crusher to accomplish their primary mission. Cost data for equipment acquisition, personnel, and maintenance were estimated and inputted into the force level model. The results obtained are shown below:

$$C = \frac{(1 + FF)(AC/SL + RMC) + CC}{365} + IC$$

$$= \frac{(1 + 0)(\$472{,}242/5 + \$35{,}000/YR) + \$165{,}988/YR}{365\ DAYS/YR} + \$2{,}526/DAY$$

$$= \$809/DAY + \$2{,}526/DAY = \$3{,}335/DAY$$

As can be seen, the impact cost per deadline day is $2,526 or three times as large as the cost directly identified to the unit of equipment and its crew.

V. COST ESTIMATING RELATIONSHIP (CER)

The recommended method for computing the deadline cost per service day for a specific unit of equipment is by the force level model. It is recognized, however, that there are situations in which an easily computed, approximate order of magnitude estimate will suffice. Based upon the results obtained from the force level model for the limited sample of four weapons systems studied, the following CER was developed.

$$C = .0006\ (\text{Acquisition Cost}) + \$32\ (\text{No. of personnel in Crew})$$

Comparison of the deadline costs per service day obtained from the CER to the values obtained from the force level model disclosed that the CER results were accurate within -7% to +11%.

VI. CONCLUSIONS

For the hardware items used as test elements in this study, it would appear that the force-level model has a fairly high degree of stability. Except for the crew pay and allowance account, estimation errors of $\pm$ 20 percent or less in the independent variables will not have a significant effect on the dependent variable. However, the crew pay and allowance account is readily computed based upon crew composition and grades for the item under study and the Military Pay and Allowance Tables and should have a very low estimating error. The remaining data required by this model are readily available for the items used in this study and for additional hardware items[4]. It is, therefore, concluded that the force-level model may be applied, and it yields a reasonable estimate of the value lost to the US Army when an item of equipment is not available because of being deadlined.

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[4]Technical Report No. 73-6 (unpublished), Comparative Cost Analysis WECOM Managed Items, I PEMA Hardware Unit Cost, II Annual Unit Operating Cost, HQ US Army Weapons Command, Cost Analysis Division, Rock Island, IL, April 1973.

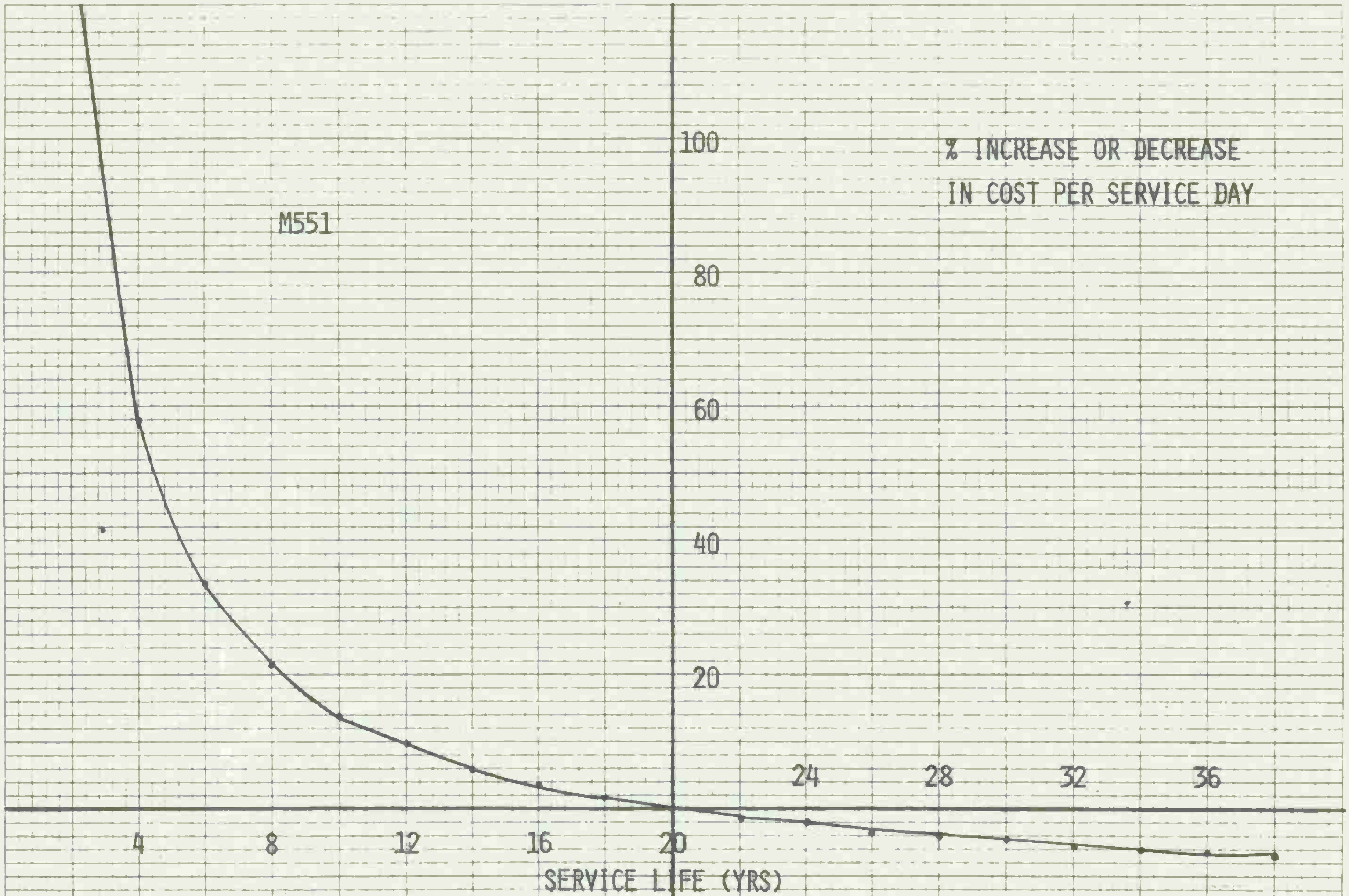

Figure 1. Service Life Sensitivity For ARAAV M551.

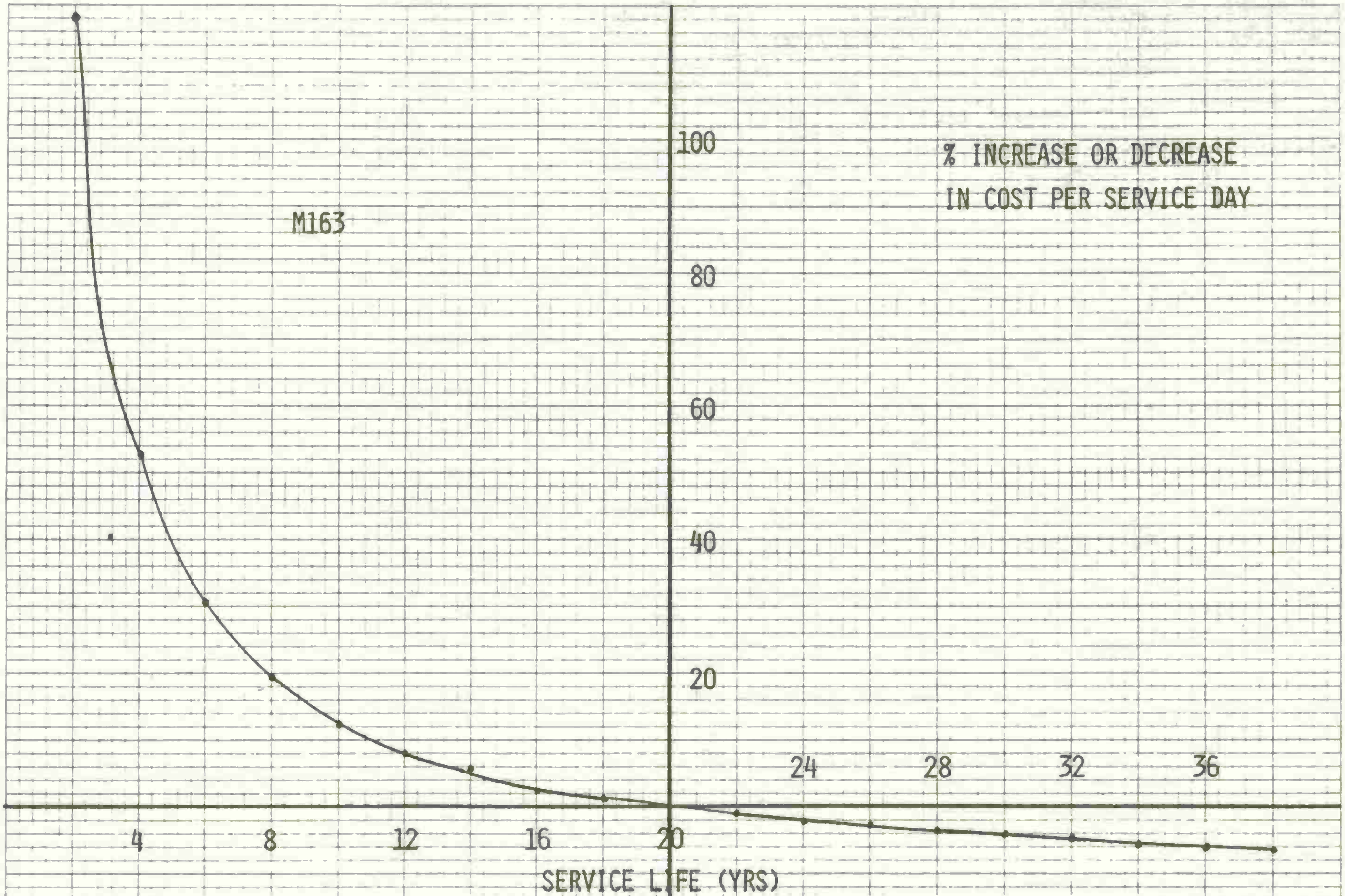

Figure 2. Service Life Sensitivity For Vulcan Air Defense System M163.

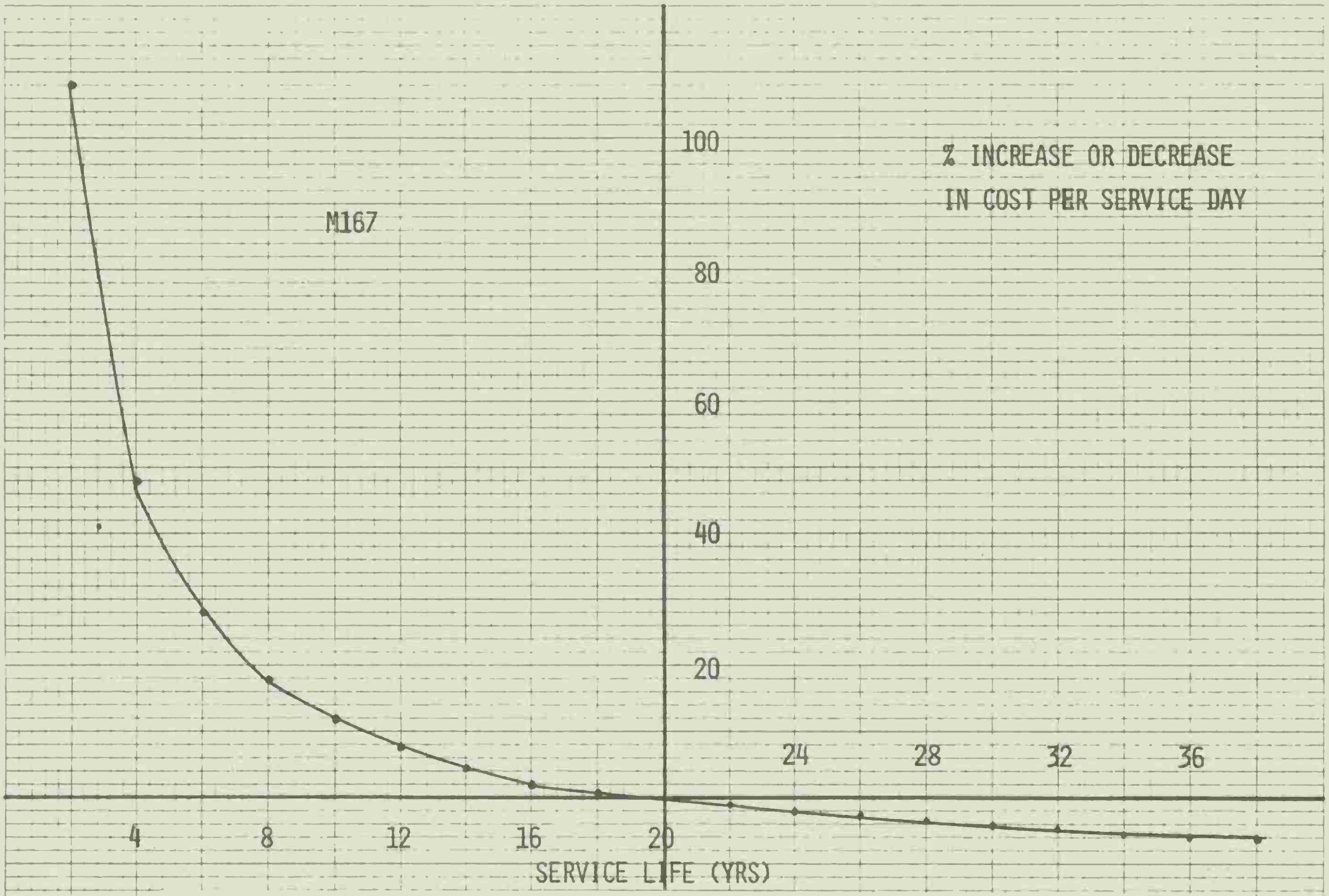

Figure 3. Service Life Sensitivity for Vulcan Air Defense System M167.

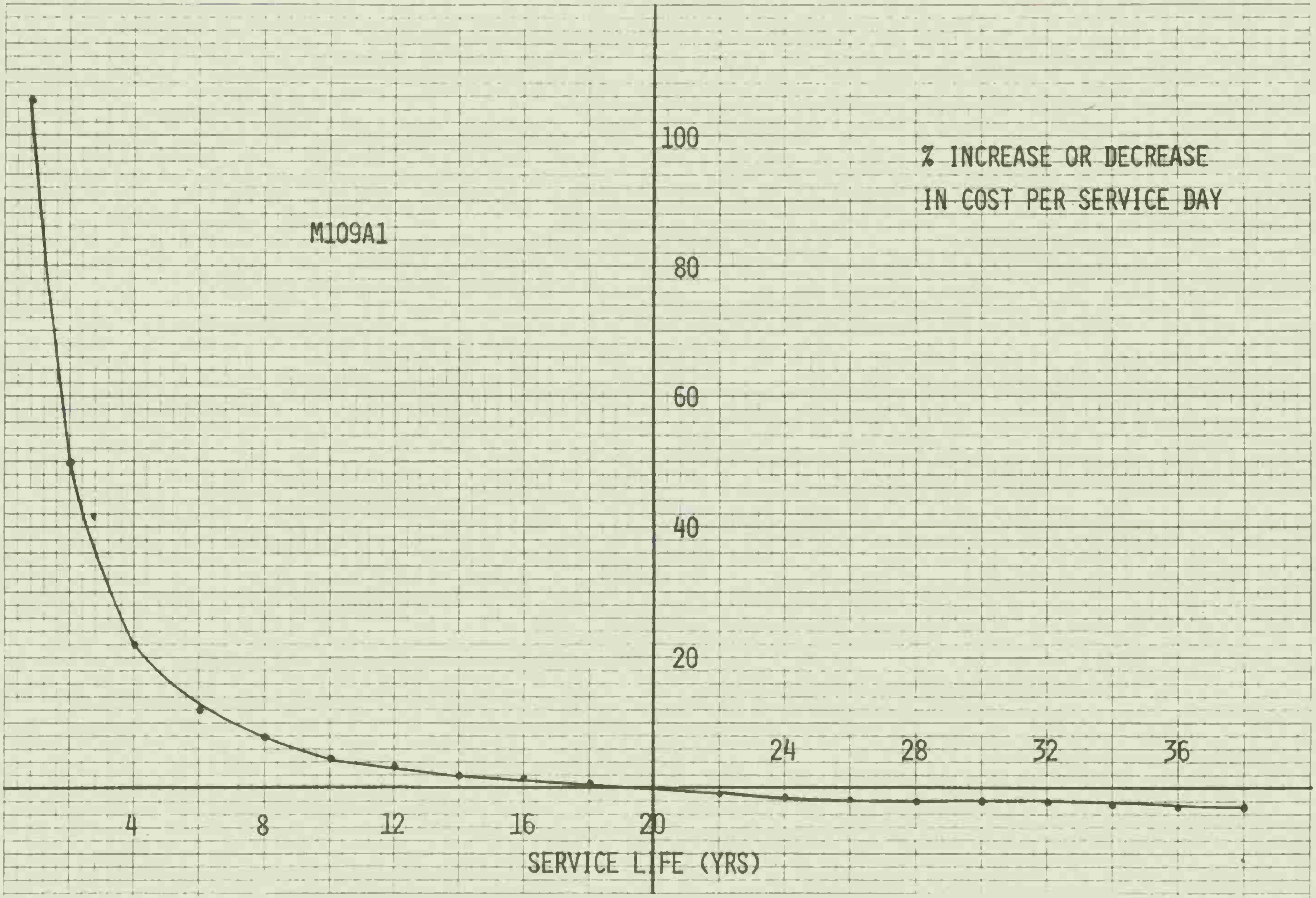

Figure 4. Service Life Sensitivity For ARAAV Howitzer M109.

APPENDIX A

DATA ELEMENTS USED TO EXERCISE THE MODEL

1. Float Factor

M551	0.033
M163	0.09
M167	0.09
M109	0.027

2. Acquisition Cost

M551	$259,930
M163	$276,377
M167	$220,416
M109	$145,812

3. Estimated Service Life

M551	20 years
M163	" "
M167	" "
M109	" "

4. Crew, Pay & Allowance - MPA

Based upon crew composition and average grade level

M551	$33,280/year
M163	$31,770/year
M167	$31,770/year
M109	$64,280/year

5. Crew, Replacement Training

Based upon the percentage of annual turnover of item 4 above

M551	$3,300/year
M163	$4,190/year
M167	$4,190/year
M109	$6,250/year

APPENDIX A (Cont'd)
DATA ELEMENTS SUPPLIED TO EXERCISE THE MODEL

6. Crew, Indirect

Developed from data obtianed from Comptroller of the Army, Cost Analysis, that the indirect cost per year for an individual soldier is $2905. This factor is multiplied by the number of personnel in the crew.

M551	$11,620/year
M163	$11,620/year
M167	$11,620/year
M109	$26,145/year

TOTAL Crew Costs (4 + 5 + 6)

M551	$48,200/year
M163	$47,580/year
M167	$47,580/year
M109	$96,675/year

7. Maintenance, Pay and Allowance - MPA

Based upon equivalent number of man-years to perform maintenance actions.

M551	$4,630/year
M163	$11,500/year
M167	$9,190/year
M109	$6,430/year

8. Maintenance, Replacement Training

Based upon a percent annual turnover of item 7 above.

M551	$1,740/year
M163	$2,590/year
M167	$2,160/year
M109	$1,500/year

9. Maintenance, Crew Indirect

Based upon a computed percent value to allocate the indirect cost per individual soldier (Item 6) to the number of equivalent man-years shown in item 7 above.

M551	$1,956/year
M163	$4,859/year
M167	$3,883/year
M109	$2,717/year

APPENDIX A (Cont'd)
DATA ELEMENTS SUPPLIED TO EXERCISE THE MODEL

10. Comsumption, Parts

M551	$14,990/year
M163	$21,320/year
M167	$16,590/year
M109	$15,020/year

11. Consumption, Petroleum Oils and Lubricants - OMA

M551	$60/year
M163	$100/year
M167	-
M109	$70/year

12. Transportation - OMA

M551	$420/year
M163	$670/year
M167	$360/year
M109	$410/year

13. Depot Maintenance

Overhaul costs prorated on an annual basis.

M551	$6,940/year
M163	$6,820/year
M167	$4,260/year
M109	$3,500/year

TOTAL Repair and Maintenance Cost (7 + 8 + 9 + 10 + 11 + 12 + 13)

M551	$30,736/year
M163	$47,859/year
M167	$36,443/year
M109	$29,697/year

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